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ABSTRACT

Analysis of students' interpretations of a complex episode of social interaction was used to illustrate three features of human plans that distinguish them from robot plans and that form a basis for a theory of the development of social action. The features illustrated are that (1) human plans are social, (2) human plans operate on interpretations, and (3) human plans are used, not just executed. Twelve students each from grades one, three-four, and six, and 12 college students were shown a videotaped skit in which one character deceives another. Many of the younger subjects considered the interaction to be cooperative, while older subjects understood that the deceiver was manipulating the victim's cooperative interpretation. A model of interacting human plans was incorporated in a notation system that was used for displaying the structure of the alternative interpretations and their mutual embeddings. This notation system contained a key concept, mutual knowledge (or belief), that incorporates the essentially social features of human plans. Implications of the model of human plans for the development of social action and cognition are discussed. (Author/FL)

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Technical Report No. 317

INTERPRETATION AND MANIPULATION IN HUMAN PLANS

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July 1984

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Abstract

An analysis of children's interpretations of a complex episode of social interaction is used to illustrate three features of human plans which distinguish them from robot plans and which form a basis for a theory of the development of social action. The features are: (a) human plans are social, (b) human plans operate on interpretations, and (c) human plans are used, not just executed. Elementary school and college subjects were shown a skit in which one character deceives another. Many of the younger subjects considered the interaction to be cooperative, while older subjects understood that the deceiver was manipulating the victim's cooperative interpretation. A model of interacting human plans is incorporated in a notation system which is used for displaying the structure of the alternative interpretations and their mutual embeddings. The notation contains a key concept, mutual knowledge (or belief), which incorporates the essentially social feature of human plans. Implications of the model of human plans for the development of social action and cognition are discussed.

Ever since the publication of Plans and the Structure of Behavior (Miller, Galanter, & Pribram, 1960), the analysis of plans has played an increasingly important role in studies of cognition and cognitive development (Friedman, Scholnick, & Cocking, in press). These analyses have drawn on formal models of plan structures and planning mechanisms developed in Artificial Intelligence work which are elegant and have wide applicability. Unfortunately, the standard AI model of a plan is weakest at accounting for what may be the most salient aspect of human planning, namely, that it occurs as a product of, and in the context of, social interaction.

Building on our earlier analyses of interacting plans (Bruce, 1980; Bruce & Newman, 1978), we now focus our attention specifically on the relationship between an individual's plan and the mutual knowledge he or she holds in common with others. We report a study of children's understanding of a social episode which highlights the ways that social plans can involve the manipulation of other people's interpretation of the ongoing interaction. The data presented here show that apparently simple social interactions can involve complex operations on mutually known plans. The analysis isolates an important aspect of this development: the ability to "step outside" of mutual knowledge. These observations contribute to an emerging developmental theory of the interpretation and manipulation of plans. In this paper, we first discuss some of the salient features of social plans. Next, we present data from a study of children's understanding of a social episode. We then present a detailed analysis of a developmental sequence of interpretations produced by the children. We conclude by suggesting a general mechanism by which complex

mutual knowledge may be built up in the course of planning a social action and in the course of the ontogenetic development of social knowledge.

Social Plans

We can best explicate the concepts that play a central role in our analysis of the children's interpretations by contrasting human or social plans with the robot plans that have played a famili. role in Artificial Intelligence over the last decade. We claim that the robot plan models represent at best a special case of human planning and plan recognition.

Extensive research devoted to developing and exploring the usefulness of various formalisms for plans (e.g., Miller, Galanter, & Pribram, 1960; Sacerdoti, 1977; Sussman, 1975) has resulted in general agreement on what a plan formalism should look like. Take, for example, the now classic problem of the "robot and blocks." A robot is in a room with several blocks. Its task is to move the blocks from some given initial configuration to a desired final configuration, for example, to stack them up in a particular order. It does this by carrying out a sequence of actions with known conditions on their use and known consequences.

The representation of the robot's problem and subsequent planning to solve it makes use of any of various formalisms, each constrained by aspects of the robot's world. First, the formalism allows descriptions of states of the world and operators for changing a given state. A state is specified by a set of propositions. Operators are functions that, if applicable, take a state and change some of the propositions so as to produce a new state. If one or more of the enabling conditions does not hold, the operator cannot be applied. The task of plan generation can then be stated as follows: Find a sequence of operators that can be applied to transform an initial state into a goal state.

Devising a plan in a world more complex than the blocks world requires a planning mechanism that can generate long sequences of operators where the choices may not be obvious. Methods have been developed for breaking large problems into subproblems, for resolving conflicts among subgoals, for debugging plans that mostly work, and so on. Nevertheless, with few exceptions, the theories and formalisms in essence exhibit a concern for plans similar in kind to the blocks world in which operators change one state into another state under specified conditions.

Robots are designed to play a helpful role in human work. Thus, we want to argue that robot plans are a peculiar subset of the plans that humans can carry out. Humans, of course, can act like robots, but only by setting aside properties that seem to us to be definitional of being human. We can make the contrast between the plans typical of AI research and plans typical of adult humans in terms of the following three distinctions.

Individual versus social. A robot plan is a plan for an individual. In the blocks world, only the robot can act. If there were other robots around, their activities would be treated as environmental complications, producing, perhaps, uncertainties about the effects of certain actions. If two or more robots were to work in concert, a supervisory plan might be needed to resolve conflicts. But, in the final analysis, the robot's plan would still be that of an individual.

In contrast, human plans are fundamentally social. It is not sufficient to characterize social plans as those that influence people rather than objects. Humans do not just act on others, they interact with others. Through language, they share in the construction of meaning, and their mutual influence is mediated by these shared meanings. Whereas

robot plans in putatively social contexts (the other robot problem) remain essentially individual, human plans are social even in apparently individual contexts. A subject of a psychological experiment, solving a problem in an isolation booth, must still work with the interpretation of the task that was formed in interaction with the experimenter (Newman, Griffin, & Cole, in press). Furthermore, tasks that experts routinely plan and carry out as individuals are almost invariably learned originally in interaction with experts and retain a socially constituted meaning for the actor (Leont'ev, 1981; Newman, Riel, & Martin, 1983).

Facts versus interpretations. Another distinction that follows from the first concerns the "objects" of robot plans versus human plans. The robot operates in a world of facts. For the robot, propositions are either true or false and operators do what they are designed to do. Consistent with the factual nature of the robot's world is its stability. The operators, the state descriptions, and the goal are preestablished and do not change fundamentally during planning. There might be changes to be made upon the discovery of a new fact, but there is no place for disputes or misinterpretations.

Working in a social world, the human planner must recognize that world models vary, not just in terms of precision or accuracy, but also in terms of perspective and interpretation. Human planning exhibits ongoing, and even retrospective, establishment of meaning. An important aspect of planful behavior for humans, in fact, is to create or modify beliefs so as to redefine states, actions, or goals. Gearhart and Newman (1980), for example, show how a nursery school teacher retrospectively establishes for herself and the children in her class that their activities were part of the plan to "draw a picture." She, or they, define the act that their

actions manifest. For the robot, on the other hand, act and action are synonymous; the meaning of an action is irrelevant.

The interpretive nature of human plans leads to a kind of fact that is simply unknown in robot plans. "Social facts" are those facts that exist by virtue of our social actions and shared social meanings (cf., Durkheim, 1964; Garfinkel, 1967). Facts such as who owns a particular item are certainly objective facts about the social world, yet they are dependent on shared recognition by the participants in the interaction. If the participants fail to agree, then the fact ceases to exist. Since social facts require the coordination of at least two participants, they cannot be reduced simply to the belief or mental state of an individual. So human social plans differ from robot plans not only in that they act upon the mental states of the individuals involved; they also act upon and manipulate the social facts that form the basis for coordinated social interaction.

Execution versus use of plans. Typically, research on robot plans has been compartmentalized. Separate computer programs handle the tasks of plan design, plan execution, and recognition of plans being executed by others. Even in cases that require coordination of the tasks (e.g., recognizing a plan by attempting to generate a plan that will produce the same actions), it is usually fairly easy to maintain a conceptual and a practical distinction among the tasks.

Social plans, on the other hand, demand an integration of design, execution, and recognition into a single task. An action may simultaneously be a step in a plan, an attempt to gain information about another's plan, and a message that communicates the plan of which it is a part. The inseparability of functions in social plans leads to a crucial

difference from robot plans: In social contexts, plans are used, not just executed. Acting in a social context requires communicating plans, that is, deliberately acting to facilitate or even cause another to recognize one's plan. Partial execution of a plan can be used to communicate certain intentions such as a threat. Likewise, the execution of an ordinary plan for a speech act can be used as a joke or an insult when carried out in an inappropriate context. In other words, humans can step back from the ordinary goals so as to use commonly known plans for uncommon purposes.

In this paper, we will concentrate our attention on the kinds of plans that provide the strongest contrast with robot plans: human plans that involve strategic deception. In the face of our broad interest in human plans, we have, admittedly, chosen a very narrow domain to discuss in this paper. Our goal is to present this single type of human plan in sufficient detail to demonstrate what we believe are very general properties. These are (a) the integration of the plans of two people; (b) the use of social facts; and, (c) the use of plans to achieve social recognition of intent.

Striking differences among the interpretations of the same social event provided by children of differing ages provide us with an analysis of how social events may be understood. Given the crucial features of social plans that we outlined above, we expected to find increasing sophistication with age in children's understanding of how plans can be used in social interactions to communicate intent and, in particular, to mislead others. In finding more and less sophisticated interpretations, where the simpler versions are components of the more complex ones, the

importance of the general properties for adult understanding of social plans is illustrated.

In what follows, we first describe in some detail children's responses in an interview study about a videotaped skit illustrating a deception. In the subsequent section, we provide a formal analysis of three typical interpretations. The formal analysis provides a theoretically motivated description of the age differences and sets out the basis for our approach to human plans and their development.

A Study of Children's Understanding of Social Plans

Strategic deception provides a good case of social planning because it highlights several of its crucial features. Deception requires a separation of the perspectives of the two actors and makes explicit the manipulation of mutual knowledge by the deceiver. Such plans are directed to social facts, and require the use of the ordinary plans. Our analysis of such episodes demonstrates how these special cases of social plans--special because they involve an individual's secret manipulation of another--are based on and appear ontogenetically to grow out of cooperative plans in which two people are asserting a reciprocal influence. Deception makes more visible processes that we believe underlie the ordinary case.

Examples of strategic interactions that are very appropriate for showing to children can be found in a somewhat unexpected source. One of Sesame Street's most famous Muppet characters, Ernie, on several occasions is found to deceive his good friend Bert. These skits are excellent as stimulus materials because their content (e.g., sharing cookies, learning about simple emotions) is well below the level of world knowledge found in average elementary school children. Furthermore, the skits are very well

acted so the interactions are very engaging. These features combine to lead even first graders to believe that they understand the interactions, even though many of them interpret the interactions quite differently from the average adult.

One of the skits, entitled "Ernie Shares Bert's Cookie," will be the object of our analysis in this paper. The title gives a hint as to the strategy involved. Bert has a cookie in his hand when Ernie bursts on the scene and tries to grab it. Bert holds it back, insisting that he is going to eat it all himself. Ernie argues that if the cookie belonged to him he would share it with Bert, but Bert does not believe him. Ernie then takes the cookie and says he will demonstrate what he would do if the cookie were his. He gets Bert to role-play, asking him to share it. When Bert asks the question, Ernie says he would be happy to share the cookie. He then proceeds to break it in half, and walks off eating his half saying: "See, I told you I would share it with you." Bert is left dumbfounded.

An interview study, reported in full by Newman (1981), was conducted using a cross-sectional sample of elementary school and college age subjects. The goals of the study were to empirically extend earlier findings about children's understanding of social interaction (Flapan, 1968) into a more complex social domain, and to ground this range of developmental observations in a theoretical framework based on the notion of interacting plans (Bruce & Newman, 1978).

Data Collection

Forty-eight subjects were interviewed to elicit their interpretations of three Bert and Ernie skits. (We will be concerned with only one of those three.) There were 12 subjects from each of grades one, three-four,

six, and college. The interviews about the cookie skit lasted about 15 to 20 minutes and consisted of showing the skit (which lasts about 2 minutes), asking the subject to retell the story, and then playing the skit again but this time stopping it at four predetermined places to conduct a clinical interview about the subject's interpretation of a particular crucial utterance and of the events in the skit up to that point. Most of the questions were aimed at eliciting the subject's interpretation of Ernie's plan, although others asked about Bert's reactions and thoughts. At the end of the skit, several questions were asked about whether Ernie was being fair.

Three Qualitatively Different Interpretations

A coding scheme specified 24 features of each subject's interpretation (Newman & Hirsch, 1980). These features generally clustered into one of three basic types of interpretation of Ernie's plan. We will be concerned primarily with these general types. As we demonstrate in the subsequent section of this paper, each interpretation consists of a different understanding of the plan that Ernie is carrying out and a different relation between the plans of the two characters. In what follows, we illustrate each type of interpretation using transcripts of the interviews.

The sincere interpretation. Twenty-two of the 48 subjects believed that Ernie was trying to get the cookie shared or otherwise sincerely trying to show Bert the proper way to act. In the opinions of these subjects, Ernie wanted part of the cookie and might even be acting unfairly, but he was not deceiving Bert. A concrete example illustrates several typical features of these interpretations.

The following excerpts are from the interview of a first grade boy. The first question of the interview concerns Ernie's assertion that he would share the cookie. The child seems suspicious of Ernie at first:

I: Ernie says: "If that cookie belonged to me, I would share it with you." Now why does he say that? What's he trying to do there?

S: He wants the cookie just as Bert does and he wants to eat it with Bert, but Bert doesn't want to.

I: What's Ernie trying to do when he says "If that cookie belonged to me, I would share it with you"?

S: He's saying he would share it with me.

I: Do you think Ernie's telling the truth, or is he lying when he says "I would share it with you"?

S: I don't think he would be telling the truth.

I: You do?

S: If there were lots of cookies I think he would, but if there's one cookie I don't think he would want to.

As this first grader continues through the skit, Ernie's intentions appear in a better light. The next stopping place is Ernie's explanation for taking Bert's cookie--that he just wants to demonstrate. What the child says at first is consistent with the notion that Ernie is trying to get Bert to believe the falsehood that he would share the cookie, but he considers Ernie to be telling the truth about the demonstration. While it is not clear in what way Ernie's statement can be considered true, at least Ernie is being portrayed as sincere in some way.

I: Okay, right there Ernie says: "I just want to demonstrate." Now why does he say that? What's he trying to do there?

S: He was going to make him believe that he would give him one half of the cookie.

I: Do you think that Ernie's lying or is he telling the truth there when he says "I just want to demonstrate"?

S: Telling the truth.

I: Telling the truth? What is Ernie going to prove?

S: That he will share the cookie.

The tape was stopped next at the point where Ernie instructs Bert to ask him (Ernie) if he would share the cookie with Bert. Now Ernie appears to be conducting a fair demonstration, but Bert thinks that he is trying to take the whole cookie. Bert is portrayed not only as anxious to eat the cookie, but as distrustful of Ernie.

I: Ernie says: "Just ask me if I'll share it with you." Now why does he say that? What's he trying to do there?

S: He wants him to ask him if he would share the cookie with him, but I don't think ( ) wants him to do it. I think he's hungry and should just go ahead and eat it.

I: He's gonna- tell me that again.

S: He wants to eat the cookie.

I: Ernie does?

S: No, yeah I mean Bert wants to go ahead and eat it. And Ernie just wants to demonstrate but Bert doesn't want to. He wants to go ahead and eat the cookie.

I: Does- what does Bert think Ernie's trying to do?

S: Trying to keep the cookie for himself.

I: So does Bert think that Ernie's gonna give him back the cookie or half the cookie or none of the cookie?

S: He thinks he's gonna eat it all ( ).

I: Bert thinks Ernie's gonna eat it all? Well, is it gonna- do you think this is a fair demonstration?

S: Yes.

I: Why, what makes you- it's a fair demonstration?

S: He breaks it in half and gives him, Bert, half of the cookie.

The tape was stopped for the last time as Bert is staring at the remains of his cookie. Bert was clearly not expecting Ernie to share the cookie fairly.

I: Bert's standing there looking down at his part of the cookie and he says: "I don't get it, I don't get it." Now, why does he say that? What's he thinking about?

S: He's thinking about Ernie doing all- breaking it in half. He didn't know that he would do that. He doesn't think- he was surprised that he shared the cookie with him.

I: What did Bert think Ernie was going to do?

S: Keep it all for himself.

I: Oh, oh I see. So he was surprised that Ernie gave him any at all? Well, how does Bert feel right now?

S: He feels nice.

I: Nice? So he is happy about what Ernie did? Well, do you think that he might be confused or not?

S: Confused.

I: Why would he be confused?

S: Because he doesn't know that Ernie- why he did that. He thought he would eat it all for himself.

The last questions concerned fairness. For this child, the problem of fairness concerns the evenness of the division. Ernie apparently thinks it is fair as long as they both got a part (or he may have unintentionally broken the cookie unevenly), but Bert and the child both think it is unfair for Ernie to have more. Ernie's sincerity in doing the demonstration is not an issue except for Bert, who doubted that Ernie would end up sharing the cookie at the end of the demonstration.

I: Who got the big half or did they both get the same size?

S: ( )

I: What?

S: Ernie, Ernie got the big half.

I: Ernie got the big half. So why did Ernie get the big half?

S: Cause he- I think he wanted more than Bert.

I: Do you think that Bert thinks it's fair what Ernie did?

S: No.

I: No, why not?

S: Because he was looking at his cookie and then he saw that he didn't have that much and Ernie took most of the cookie.

I: Well, what about Ernie? Does Ernie think it's fair?

S: Yeah.

I: Yeah, why does Ernie think it's fair?

S: Because he gave him the part of the cookie and he gave himself part of the cookie.

I: Okay, do you think it's fair?

S: Well, no.

I: No, why not?

S: Because Ernie got more than Bert.

Usually subjects who thought Ernie was telling the truth about the demonstration also thought he was being fair. But this was not always the case. Like this child, five others thought that Ernie divided the cookie unevenly in his own favor. These subjects, however, consistently thought that Ernie would think he was being fair. Overall, then, subjects coded as having "sincere" interpretations saw Ernie as both truthful and intending to be fair.

The trick interpretation. In general terms, these plans were ones that contained any significant amount of trickery except tricks of the particular kind coded for by the last category. In general, the tricks were ways for Ernie to get the cookie by making Bert think, for the moment, that Ernie was doing something he was not actually trying to do.

Thirteen of the 48 subjects were coded in this way. The following excerpts from a representative subject illustrate the important features.

The interview about the cookie skit with this sixth grade boy began as follows:

I: Okay, Ernie says: "If that cookie belonged to me, I'd share it with you." Now, why does he say that? What's he trying to do there?

S: He's trying to con him into giving him a piece 'cause he wants some. He knows he really wouldn't, but he's just saying that like to get him to give him a piece of the cookie, give him some cookie so he could eat it.

I: So is Ernie lying, or is he telling him the truth when he says that?

S: Lying.

I: He's lying. Well, what do you mean he's conning him? What does conning mean?

S: Well he's tricking him into giving him the cookie by saying he'd share it with me, and then demonstrating it, then actually eating the cookie.

It is quite clear that Ernie is tricking Bert and that the demonstration is not sincere. It seems that "actually eating the cookie" is somehow at the heart of this trick.

The next stopping place began with the question about Ernie.

I: Here Ernie says: "I just want to demonstrate." Now what, why does he say that, what's he trying to do there?

S: Well, this is the part when he jerks, jokes, tricks him, demonstrating 'cause usually you wouldn't eat it and not get- I eat my half and then you eat your half, but he ate the half so like he was just setting him up, and then he finally took the half a cookie, and then he was- Bert was left with half a cookie and he got mad.

Now it is quite clear that the trick involved eating the cookie which Bert would not expect because "usually you wouldn't eat it."

The final questions about fairness reveal some more aspects of Ernie's plan:

I: Okay, did Ernie think it was fair or not fair?

S: Ernie knew that it wasn't quite fair 'cause Ernie knew that he wouldn't really share, share the cookie any other time, so Ernie knew that it really wasn't that fair that he was saying and putting it, you know, telling Bert, making Bert think that Ernie thinks it's like fair, but Ernie knew it wasn't, he was just trying to do that to get the cookie.

I: Okay, I guess I got one more question about this then. Was Ernie being mean or- Ernie wasn't being fair but was he being like mean or he just didn't know any better?

S: Well, sort of being mean because of the way he did it, 'cause he knew that, you know, by demonstrating it he can get a piece without having to wait for Bert to, you know.

Several aspects of what Ernie did are mentioned as reasons for Ernie, himself, to think his actions were unfair. First, Ernie knew he would not really share the cookie if it were his. Thus, from the beginning, the demonstration was insincere. Second, Ernie was trying to make Bert think that he thought the demonstration (or his conduct in general) was fair when it was only directed at getting the cookie. The third aspect of Ernie's deliberate unfairness was that he short-circuited the proper procedure of giving the cookie back to Bert and allowing Bert to decide if he wants to share.

The con interpretation. The coding scheme defined a "con" as a plan in which Ernie is trying to get part of the cookie, but in which he is also conning Bert into thinking (or momentarily believing or being confused as to whether or not) he is sincerely concerned with sharing. A common feature of conning is that the victim is not sure whether or not somebody has just done him a favor. This twist requires a retrospective interpretation of Ernie's actions, which makes the con considerably different from the other tricks in the corpus.

Thirteen subjects interpreted Ernie's plan this way. An undergraduate discusses Bert's view of the demonstration as follows:

I: What does Bert think Ernie's trying to do?

S: I don't know if Bert ever catches on. He's so dumb sometimes.

I: What does he think that Ernie's doing?

S: What does he think that Ernie's trying to do? Just show him. I think that Bert thinks that Ernie's just trying to show him that he should share it, how Ernie would share if he had the cookie. What else could he be thinking?

I: Well, he might, I'm not sure he may not, well, for instance, do you think that he thinks that Ernie's gonna give him the cookie back or half the cookie back or none of the cookie back?

S: Well Bert, I don't know, he's always being taken by Ernie so it shouldn't surprise him if Ernie didn't give any of the cookie back, but it just depends on Bert, how dumb, I don't know, I don't know Bert personally.

The subject seems to believe that Bert is being taken in by Ernie at this point in the skit. But she cannot tell whether Bert suspects that Ernie is going to take some of the cookie because she does not have enough information about how dumb Bert really is.

Bert's mental state and Ernie's plan become very clear at the last stopping place.

I: Bert's looking down at his part of the cookie saying I don't get it, I don't get it. Now, why does he say that, what's he thinking about?

S: He's going, he's so dense, he just doesn't know what happened. He's confused, he doesn't understand how he was taken by Ernie again.

I: Do you think Ernie was trying to get him confused or not?

S: Oh, yeah. Because at the end I think Ernie was trying to make Bert feel like Ernie had done him a favor. You know, that's what friends are for, Bert.

I: So you think that Ernie intended for Bert to feel that maybe he had done him a favor in sharing the cookie?

S: Yes.

I: Do you think that Ernie- why would Ernie want that, or wanted Bert to feel like that?

S: To confuse him.

I: Why would Ernie want Bert to be confused?

S: So that Bert can't say: "You took half of my cookie. 'Cause Bert asked Ernie to share half of Ernie's cookie with him, right?

There were several different interpretations of Ernie's goal that shared the notion that Ernie was in some way defusing Bert's anger. For example, this sixth grader believed Ernie was trying to get Bert to think that the cookie actually belonged to Ernie.

I: What's not fair about it?

S: Well, Ernie tricked him, Ernie tricked Bert into giving him the cookie.

I: How did he tricked him into giving him the cookie?

S: Well it was sort of like (pause) he tricked Bert into thinking that the cookie was his and he ate the half, he ate a half.

In another variation, Ernie was viewed as trying to maintain his friendship with Bert. For example, a fourth grader gave the following interpretation:

I: You think that Ernie was trying to get Bert confused?

S: Yeah, so they would still be friends and he'd get to con more for himself.

These excerpts illustrate the essence of the con interpretation as one in which Ernie is understood as getting Bert to think that, for one reason or another, he should be grateful for Ernie's generosity or at least not be angry about Ernie's taking half the cookie.

Relation of Interpretation to Grade

Table 1 displays the results of the coding for basic types of interpretation. When both age and interpretation type are considered as ordinal scales, there is a significant relation between grade of subject

Table 1

Frequency of Interpretation Types for Each Grade

	Grade of Subject				
Interpretation	1st	3rd-4th	6th	College	Total
Sincere	11	5	4	2	22
Trick	1	3	5	4	13
Con	0	4	3	6	13
Total	12	12	12	12	12

and the three plan types. Kendall's tau gives a correlation of .47 ($p < .001$). It is clear from the table, however, that this correlation is mostly a result of the contrast between the sincere interpretation and the two categories of insincerity (trick and con). Turning now to a formal analysis of these interpretations, we see a fundamental difference between the sincere and insincere interpretations. In addition, our analysis of the differences between the trick and con interpretations displays a more subtle but nevertheless important feature of human plans.

A Model of Understanding Social Plans

The differences among the three interpretations concern the way that the same basic information about sharing comes into play. How it is used, at what levels of belief, and to what ends are quite different in the three cases. As we will see, these differences can be characterized in terms of plans of increasing complexity that reflect the developmental differences among the interpretations. Our analyses provide an explicit representation of each of the basic interpretation types which illustrate some of the formal properties that are central to human plans.

Our model of interacting plans is incorporated into a notation system that serves as a way of representing the various interpretations. The notation system itself is a theory of the necessary and sufficient elements for constructing such representations. At present, the notation is purely a paper-and-pencil technique, although Cohen and his colleagues (Cohen & Perrault, 1979) have implemented a compatible model of the planning of speech acts as a computer program. Nevertheless, the definitions of the elements allow for the systematic determination of what facts and intentions are understood by which characters. When new facts

are added to the representation at specific levels, their belief status for either character can be determined readily.

Representing Perspectives

In the notation, the perspectives of the characters are represented by "belief spaces," which are labeled boxes that contain beliefs, plans, and other belief spaces. Thus, multiple embeddings of beliefs within beliefs are readily shown. Facts about the world are always represented as somebody's beliefs in this notation. The term "belief" is thus being used very broadly to cover any aspect of the interactive situation that is relevant to the formulation of the plan.

There is one special kind of belief space--the mutual belief space--that is attributed simultaneously to both characters. We should note that we use "mutual belief" instead of "mutual knowledge" for reasons of simplicity. We are not claiming that nobody has knowledge of the world. There are, however, many cases in which a character's beliefs about what is mutually known are mistaken.

We can illustrate the derivation of mutual belief by starting with a simple state (represented by an oval), namely, the fact that Bert owns the cookie, which was established when Ernie first walked on the scene. Figure 1 shows one possibility from the viewer's perspective. Here, the viewer is represented as believing that Ernie believes the fact and that Bert believes the fact. This is not, however, an adequate representation because Ernie and Bert are both looking at the same cookie and looking at each other looking at the cookie. So we might then wish to represent within each character's belief spaces the fact that the other believes the fact also, as in Figure 2. In this diagram we have used arrows to indicate that the embedded spaces are really the same as the outside

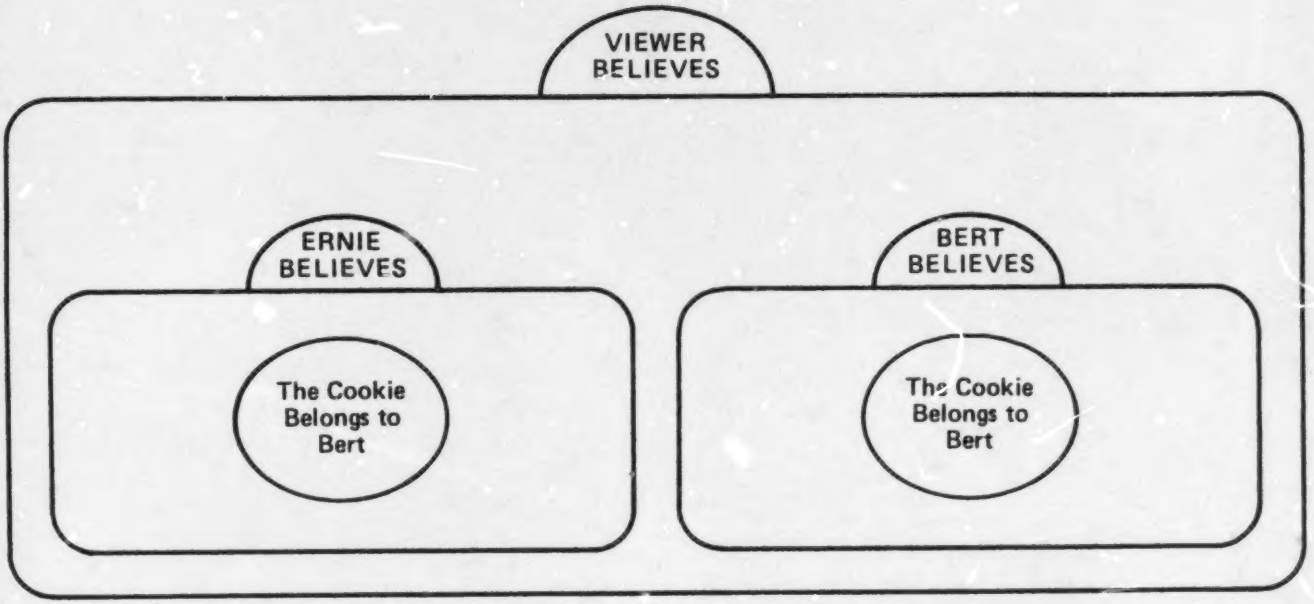

Figure 1. A possible viewer's perspective on Ernie and Bert.

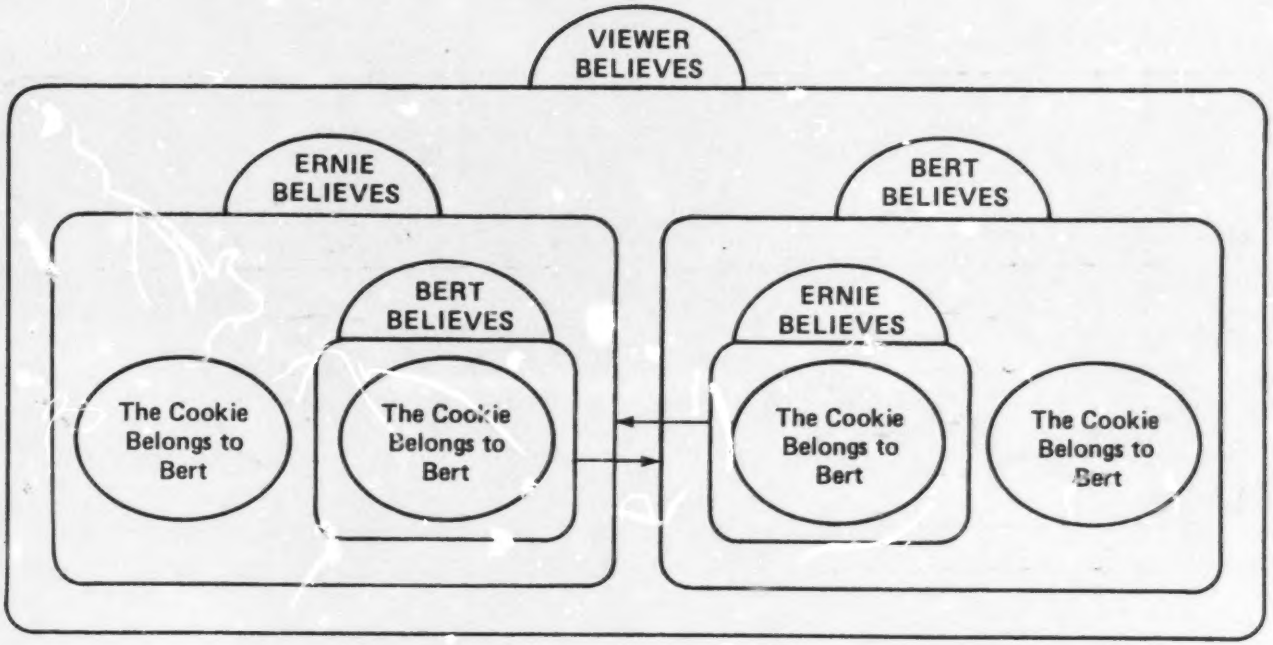

Figure 2. Another possible viewer's perspective on Ernie and Bert.

spaces of the other character. It should be clear that we have set up an endless loop, since now the Vb Eb Bb space will also have to include the Eb space contained in the Vb Bb Eb space, and so on. This situation should be reminiscent of Schiffer's (1972) concept of mutual knowledge, which he defined as a set of propositions like the following:

Eb X (where X is the fact of Bert's owning the cookie)
Bb X
Eb Bb X
Bb Eb X
Eb Bb Eb X
Bb Eb Bb X
and so on . . .

Computationally, an infinite regress can be a problem, and Cohen (1978) has shown how mutual belief can be represented finitely and processed algorithmically. The finite representation is consistent with the psychological intuition that mutual belief is really very simple (Clark & Marshall, 1981). Facts that are mutually believed are experienced simply as objective facts that are clear to anyone. The indefinite recursion indicates a logical potential, but not the ordinary experience of people in interaction. Accordingly, we define a kind of belief space in our notation that represents mutual belief directly (see Figure 3). The mutual belief space is particularly useful for representing interacting plans such as Ernie's strategies because, as we will see, it is the mutual beliefs that Ernie manipulates.

In Figure 4 we see the basic structure of strategic interaction. Here, there is a mutual belief space containing the state representing Ernie's sincerity. This space is contained within Bert's belief space, indicating that this mutual belief is Bert's belief about what is mutually believed. (When, as in this diagram, one belief space consists entirely of a lower belief space, only one box is used.) Bert's perspective, in

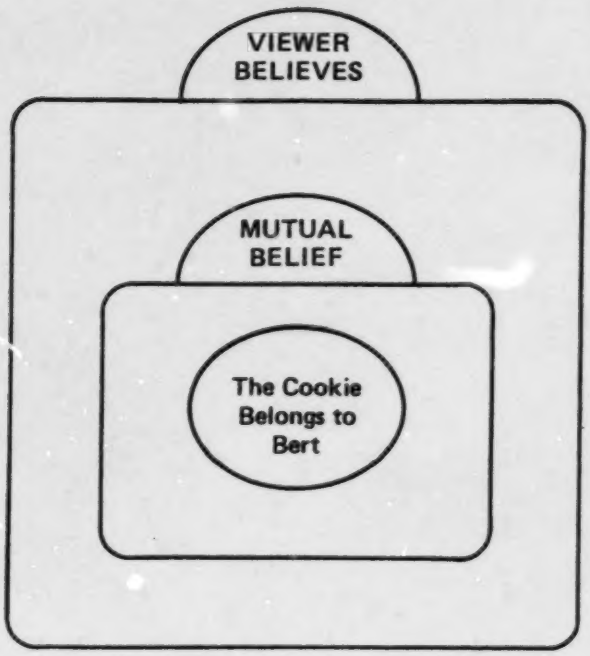

Figure 3. A viewer's perspective on a mutual belief of Ernie and Bert.

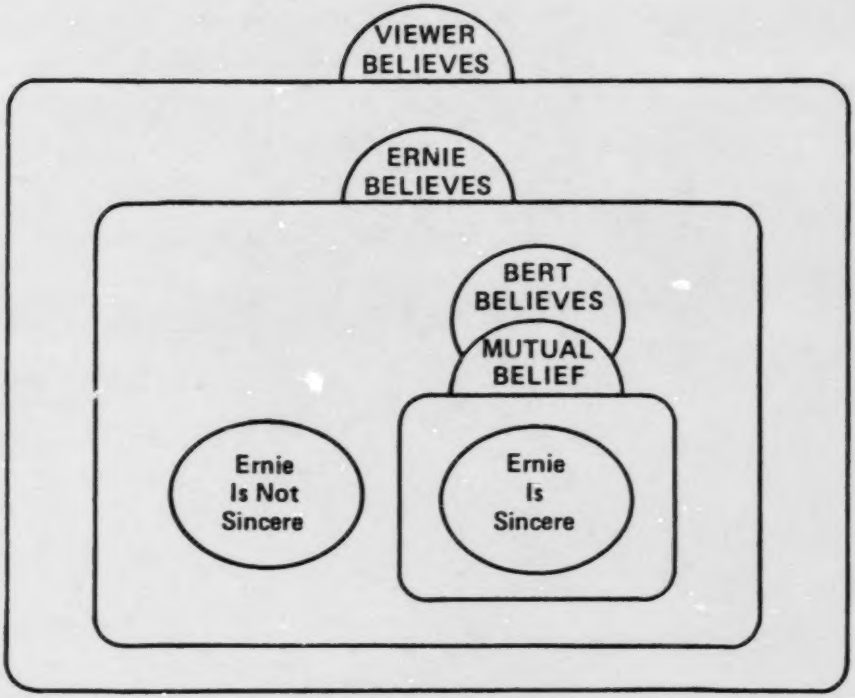

Figure 4. A viewer's perspective on a strategic deception by Ernie.

turn, is contained within Ernie's belief space, indicating that it represents what Ernie thinks Bert believes to be mutually believed. But notice also that inside the outermost space is another state that contradicts the one that (Ernie thinks) Bert believes is mutually believed. A basic principle of the notation is that spaces are opaque to the spaces contained within them. That is, Ernie can see both his own insincerity and Bert's belief that Ernie is interacting with him sincerely, but (Ernie thinks that) Bert, from his perspective, cannot see that Ernie is really being insincere.

Representations of Three Interpretations

In what follows, we provide representations of the three interpretations discussed in the previous section. These are, of course, our interpretation of the subjects' interpretations. No one subject gave explicitly all the details we need to reconstruct a coherent plan. The notation itself places constraints on the representations, but the representations must ultimately be judged in terms of commonsense plausibility as an account of what subjects said.

The pretend scenario. Figure 5 shows a hypothetical episode. It represents the pretend scenario that Ernie constructs in order to (pretend to) demonstrate that he would share the cookie. This scenario is part of all the interpretations, and appears in abbreviated form in all of the subsequent diagrams. Since it is a relatively simple sequence of events, it also serves as an introduction to the essential nodes and relations of the notation system. We list these features and their notational conventions in Table 2.

The events are enclosed in a dotted line, which indicates that this belief space is hypothetical (or in this case, pretend). At the top, the

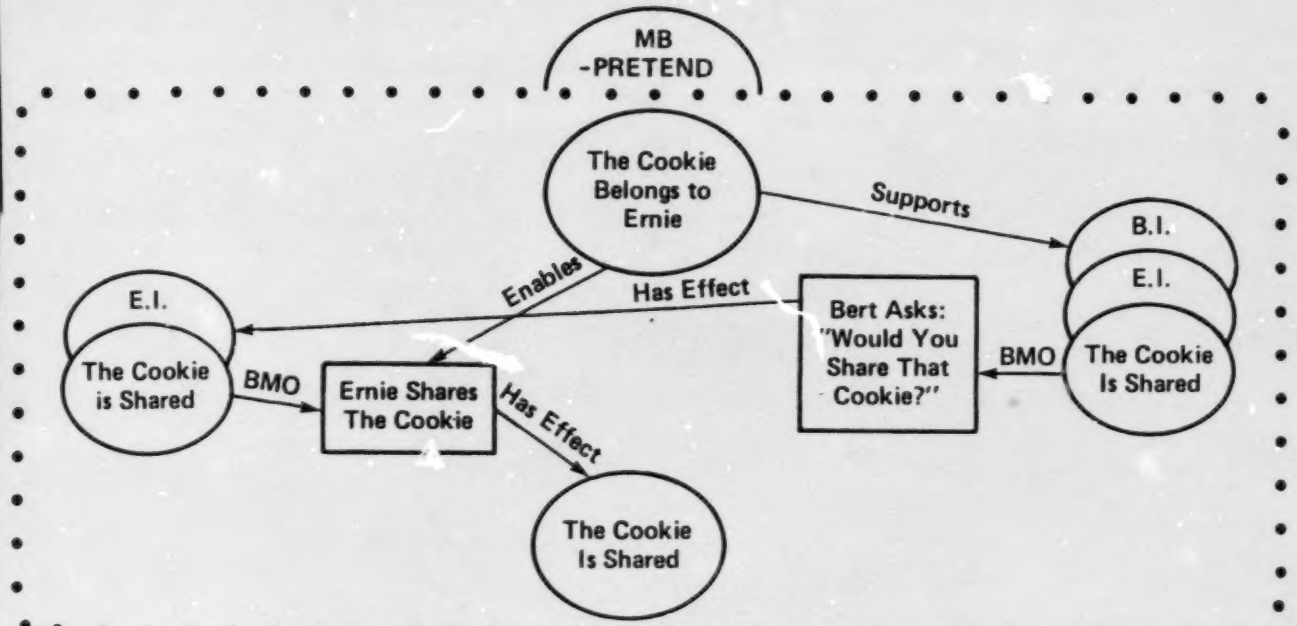

Figure 5. The cookie skit: the pretend scenario.

Table 2

Conventions Used in the Notation

Belief Spaces	
Ordinary	Solid line
Hypothetical	dotted line
Nodes	
States	Ovals
Mental States	Embedded ovals labeled either "I" for intention or "B" for believes
Actions	Squares
Relations (indicated by labeled arrows)	
Specifies	Sp
By Means Of	BMO
Has Effect	
Has Side Effect	
Produces	
Supports	
Enables	
Markers (used to highlight features but are not part of the plan)	
Same As "Virtual nodes"	are indicated by dashed lines

belief space is labeled as "MB-Pretend," which simply indicates that it is a mutually believed pretend space. Ernie's role in the scenario (his intentions and actions) appear on the left while Bert's is on the right. Ernie's highest level intentions appear on the far left.

As the scenario begins, Ernie owns the cookie (time goes from top to bottom of the figure). Bert forms the intention to get Ernie to share the cookie. This is supported by the fact that the cookie (in this scenario) belongs to Ernie. Bert's intention to get Ernie to share is carried out by means of asking Ernie, "Would you share that cookie?" Bert's speech act has the effect of creating in Ernie the intention to share the cookie. Ernie's intention is realized, in turn, by his action of sharing the cookie. His action has the effect of the cookie's being shared, which is both a physical and a social fact at the end of the scenario.

The fact that Ernie owns the cookie (in the pretend scenario) makes Bert's request a reasonable course of action (as indicated by the supports relation). He could have done other things (such as trick Ernie, for example), but asking Ernie to share is the expected course to take. The diagram shows also that ownership of the cookie enables Ernie to share it. This enablement is a necessary condition. Because sharing is a socially constituted act, it has a set of "felicity conditions" just as a speech act (Austin, 1962; Searle, 1969), that is, a set of conditions that must be met before one can say that the act was properly accomplished. Some of these felicity conditions are definitional of the act in question (Katz, 1980); without them one would not say that the act was improper, but nonexistent. Ownership appears to bear such a necessary relation to sharing: one has not shared if the object was not one's to share.

This is, of course, all pretend. A cookie that is divided up as part of a pretend scenario is not actually shared in real life either.

The sincere plan. We have seen that many subjects consider Ernie's intentions in the Cookie skit to be honorable, or at least not aimed at deceiving Bert. Figure 6 represents such an interpretation. What is shown here is Ernie's plan leading up to the enactment of sharing. (Bert's role in the plan is not shown, but if it were, it would be represented within the same mutual belief space as Ernie's plan.) Ernie's plan begins at the left of the mutual belief space. Ernie is trying to consume some cookie, but since the cookie belongs to Bert (in real life), Ernie decides to try to get Bert to share it with him. But it is not as easy for Ernie here as it is for Bert in the pretend scenario--he cannot just ask Bert. (In the skit he tried that, but Bert flatly refused.) Ernie first has to convince Bert that Ernie would share the cookie if the cookie were his. So Ernie establishes the pretend scenario and enacts sharing as a way of "demonstrating" what he would do.

Ernie's action is shown as having several effects. First, he establishes the pretend scenario itself (shown here without Bert's role). Second, he enters the pretend intention into the scenario. And, third, his action has a side effect of Ernie's actually holding onto half of the cookie (a consequence of using the real cookie as a prop). In this interpretation, Ernie's holding half the cookie is not a planful consequence of the demonstration.

The essential feature of the share interpretation is that Ernie's plan can be represented entirely within mutual belief space. That is, both Bert and Ernie are aware of the intentions indicated (and are aware that the other is aware etc.). This representation of Ernie's plan does

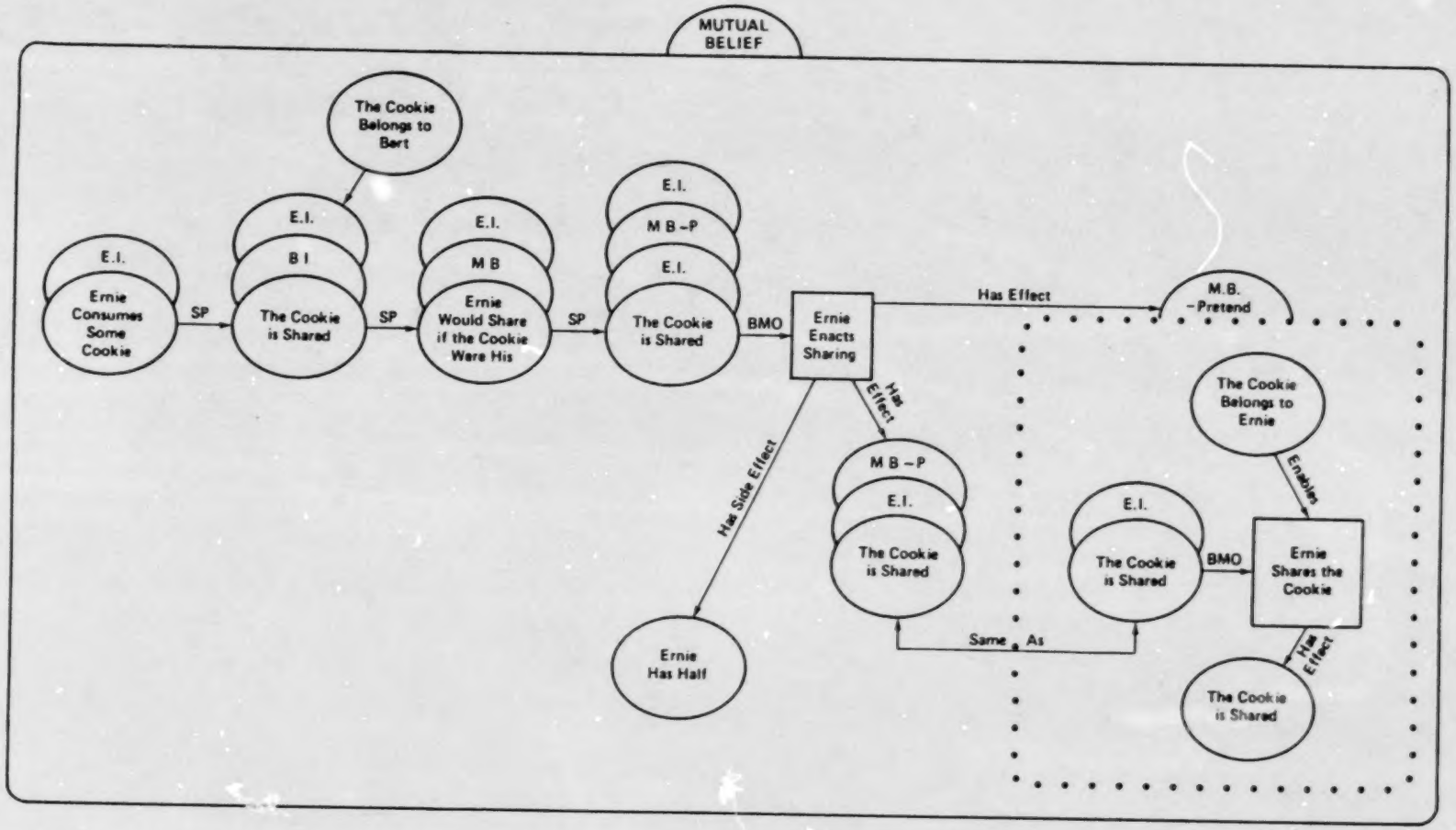

Figure 6. The cookie skit: the sincere plan.

not disappear in the more sophisticated interpretations. It remains as the basis for Ernie's deception.

The trick plan. Figure 7 represents an interpretation of Ernie's plan in which Ernie is deceiving Bert. This diagram shows the situation from Ernie's point of view. Ernie's real plan is shown in the space labeled "Ernie believes." Contained within Ernie's beliefs is Ernie's representation of Bert's perspective. Bert's perspective consists entirely of the mutual belief space that we saw in the previous figure. But now, within the mutual belief space certain nodes are represented with dashed lines. These "virtual states" are states which Ernie does not actually think are mutually believed. Toward the right is the now familiar Pretend space. This space now contains an extra Action (Ernie eats the rest of the cookie) that was not there in the Sincere plan. This pretend action is at the heart of the plan Ernie is trying to carry out.

Essentially Ernie's plan is to go ahead and eat the cookie after he pretends to share it, and to do this as if eating were still part of the pretend. This plan can best be explained by starting with Ernie's pretend action of eating the cookie (within MB-P) and tracing its antecedents outward. Within the scenario, it is reasonable that Ernie should eat the cookie since it belongs to him. So, in this plan, Ernie simply extends the scenario to the next step that would ordinarily happen in such sharing episodes. The key to the trick is that Ernie carries off the eating as though it were a legitimate part of the pretend scenario before Bert has time to realize it and to object.

Within the mutual belief space (which is identical to Bert's perspective), Ernie enacts the eating as though it were somehow specified by Ernie's hypothetical demonstration. The enactment of eating has the

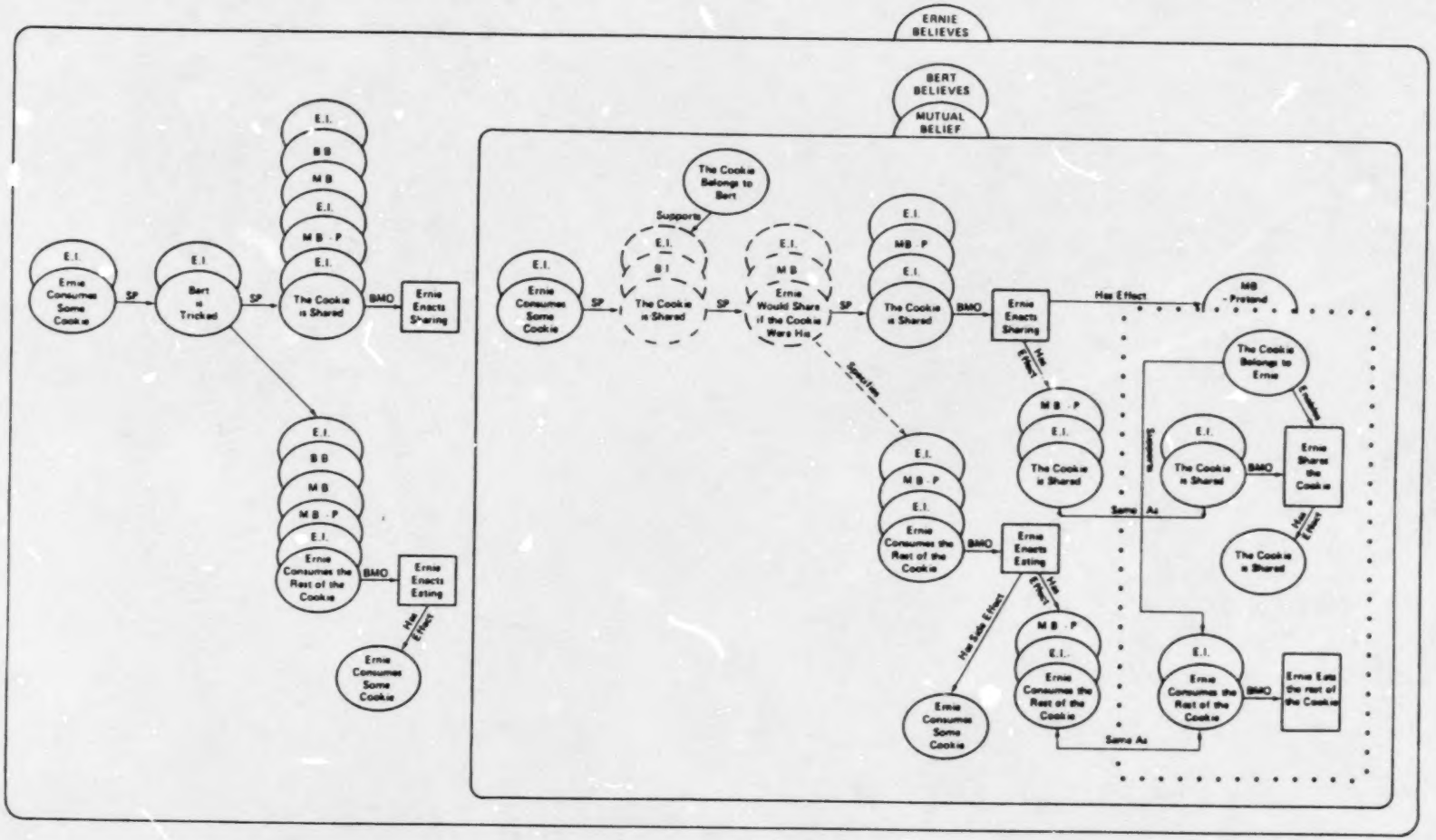

Figure 7. The cookie skit: the trick plan.

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side effect of Ernie's consuming some cookie. Although this satisfies Ernie's highest level intention, from Bert's perspective it appears just as a side effect of the demonstration.

Ernie's real plan to trick Bert contains two actions that simply reflect the actions within mutual belief. The intentions behind these actions, however are very different from those within Bert's perspective. The multiply embedded intentions in Ernie's perspective simply mean that he intends to create the impression that he is intending to demonstrate that he would share. But from this perspective, Ernie sees the state of having consumed some cookie as an effect rather than a side effect of the action. Unlike in the plan that Bert thinks is mutually believed, the intention to enact eating is specified by the intention to trick Bert rather than the intention to demonstrate his generosity.

How do Ernie's real actions satisfy their real intentions? It is important to note that the virtual (indicated by dashed lines) intentions got placed into Bert's belief space (in this case into Bb-MB) as inferences on the basis of Ernie's verbal and nonverbal actions, and from beliefs Bert assumes to be held in common. Thus, Ernie can place virtual versions of his intentions into Bert's mutual belief space simply by acting as though he had those intentions.

It can be seen in this diagram that the number of places where the real plan conflicts with the virtual plan is relatively small. Ernie can carry out most of the actions as though they were sincere because it is only some of the higher level intentions that are at issue in the deception. The mutual belief space in this figure is substantially the same as the one in Figure 6. Ernie's trick involves throwing an extra action into the pretend scenario but, more importantly, it involves

carrying out the demonstration while only appearing to be doing it for the reasons shown in Figure 6.

The con plan. Figure 8 represents a con interpretation of the cookie skit. In Figure 8, as in Figure 7, the mutual belief space is what Ernie is getting Bert to think is mutually believed.

Ernie's plan is to manipulate the contents of the mutual belief space so that he not only gets some of the cookie, but gets Bert not to be angry about it. Essentially, the plan is to get Bert to think that Ernie had actually shared the cookie with Bert. Ernie gets Bert to think that he shared the cookie by doing several things which presuppose that he has shared the cookie. This is done by subtly undoing the pretend scenario, thus causing the social and mental facts contained in it to become true of the surrounding mutual belief space. This is a rather complicated maneuver.

The plan has two parts: First, the pretend scenario is established much as it was in the trick plan. In the upper left of the diagram is Ernie's plan to establish the pretend. This is reflected within the mutual belief space, just as it was for the trick plan. As in the trick plan, two of the intentional states are virtual.

In the second part of the plan, the pretend scenario is undone, leaving Bert thinking that the pretend events were what actually happened. It can be traced beginning at the middle left of the diagram. Ernie wants to keep Bert from being angry. This (combined with the desire to eat some of the cookie) specifies the plan to con Bert. Bert will not be angry if Ernie can get him to think (i.e., to assume that it is mutual knowledge) that Ernie had shared the cookie. Ernie can do this by getting Bert to think that the cookie belongs to Ernie. It must be understood that Ernie

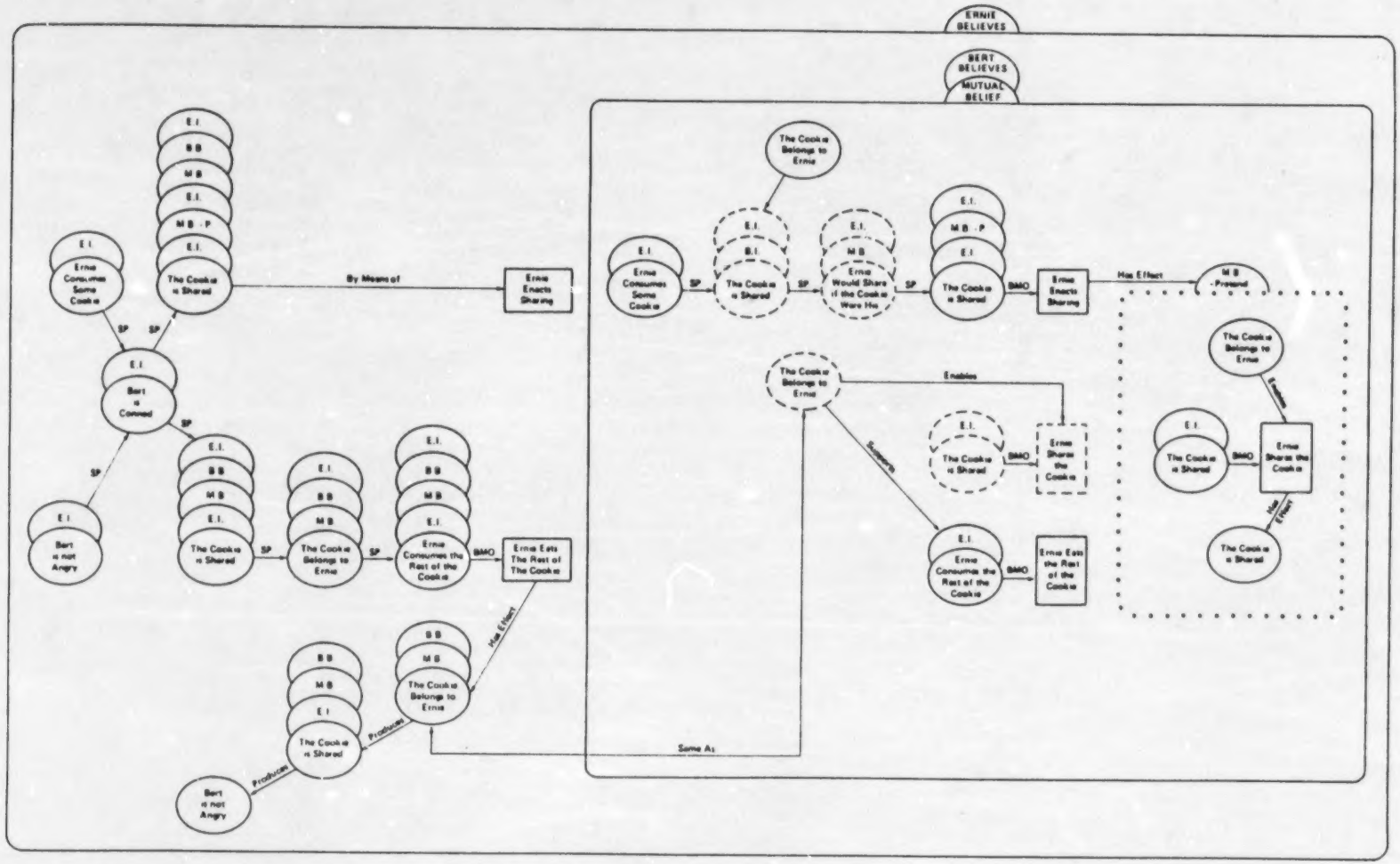

Figure 8. The cookie skit: the con plan.

expects his actions to have their effects retrospectively. This is reflected in the representation where, within the mutual belief space (as Bert understands it), the effects (as Ernie understands them) appear as supporting and enabling preconditions rather than as effects.

In the discussion of the trick plan, we pointed out that the cookie belonging to Ernie was a precondition for Ernie's legitimately eating the rest of it within the pretend scenario. That somewhat unremarkable fact was part of what helped Ernie to slip the enactment of eating past Bert before Bert could realize the trick. In the con plan, the supports relation operates in the opposite direction. Since eating the rest of the cookie presupposes that Ernie owns it, by means of eating it Ernie can get Bert to believe that he owns it. Thus, in the "Ernie believes" space, (Bert's) mutual belief in the cookie's belonging to Ernie is the effect of Ernie's eating it, while in the "Bert believes-mutual belief" space, Ernie's (virtual) ownership of the cookie is seen as supporting Ernie's intention to eat the rest of it. While Ernie's ownership of the cookie supports his eating the rest of it, it is a necessary condition for his having shared it with Bert. Insofar as Ernie's action has the effect of Bert's thinking that it is mutually believed that Ernie owns the cookie, Ernie's action also helps to produce the belief in Bert that Ernie has shared the cookie.[1] For this, Bert is grateful.

"Scripts" and Strategy

Sharing is a cultural practice with known rules, and it is a plausible assumption that all the subjects in the study understood the procedure. Different interpretations of the skit can thus be attributed to how the subjects saw this piece of knowledge being used by Ernie in carrying out his plan.

Borrowing Schank and Abelson's (1977) term, we can call this bit of knowledge about sharing a "script," that is, a general schema for an event that can be instantiated with particular values for any actual episode. As we saw in Figure 5, some of the important features of this script are: (a) at the beginning of the event, actor A owns some object, X, that actor B (and perhaps others) also want (A usually also wants some of X, which accounts for why sharing is a generous act); (b) A distributes X in some equitable way, and this distribution is done publicly so that it is clear to all concerned that X is shared. It can be seen that mutual belief is already built into this script. Ownership, for instance, is the kind of social fact that requires mutual recognition to be maintained (Newman, 1978). So, while there are two roles to the script, we have located the events and understandings entirely within a mutual belief space.

The sharing script is a central component of each of the interpretations, and the differences among the plans can be accounted for by the various ways that Ernie uses the script in planning his strategy. The sincere plan, while relatively simple, does show one way that the script may be used. Since both Bert and Ernie know the script, Ernie can get Bert to help him enact it as a way of showing Bert what he would do in a hypothetical situation. In this case, Ernie's plan is completely out in the open. His method of using the script is, itself, mutually known.

Ernie's use of the script in the trick plan is kept a secret from Bert. He uses the fact that, ordinarily, the actor doing the sharing would also want some of X. Thus, the script for the enactment could quite naturally include the sharer eating his part after sharing the cookie. Because Ernie can expect Bert to expect it, he is able to slip the eating in before Bert has time to think. In the con plan, Ernie also uses the

fact that he and Bert share the script in order to take advantage of Bert. But instead of defining an extra event as still within the enactment of the script, he makes it appear that enacting the script was not really an enactment. This is accomplished partially by taking advantage of assumptions of the script to make it appear that he actually owned the cookie.

In each case the script, insofar as it can be assumed to be shared, is a resource for Ernie. While culturally shared knowledge such as scripts are essential for accomplishing social interactions, it accounts for only a small part of how these interactions are done. The scripts themselves do not specify when or how they are to be called up to deal with particular problems. Scripts represent how things are "ordinarily" done, so, in general, actors can assume that the elements of the script are shared with others with whom they are interacting. Strategic interaction requires stepping outside of mutual knowledge. Only from that standpoint can the other's understandings be manipulated.

Social Plans and Human Development

Our analysis of the interpretations of Ernie's plan demonstrates the importance of mutual knowledge as a basis for deceptive interaction. Our model of social plans, however, has a more general utility than as an account for this narrow domain of human action. First of all, the ability to see how another person will understand the shared situation is equally important for cooperative interaction. Tracking down and repairing a misunderstanding requires in many ways the same kind of skills that Ernie displays.

Second, our model provides the basis for a reinterpretation of some of the phenomena in the domain of social cognitive development (Newman,

1983). The interpretive abilities that we saw in the older subjects is often called perspective-taking (Flavell, Botkin, Fry, Wright, & Jarvis, 1968; Shantz, 1975); that is, subjects viewing the skit must distinguish between the perspectives of the two characters in order to follow Ernie's deception. But, as we saw, Bert's perspective consists simply of the mutual beliefs that anybody would have who took Ernie at his word (in fact, those that many of the younger subjects attributed to Ernie). So the subject does not have to form a representation of Bert's perspective independent of the shared situation of the interaction. In other words, the intentions and other states contained in Bert's perspective are not private thoughts. What is usually understood by perspective-taking, then, really applies only to the representation of Ernie (when he is seen as tricking Bert). We have to be careful to distinguish between representing intentions and beliefs as private thoughts, and representing them as ordinary mutual knowledge. Only the former strictly require perspective-taking. The latter require only the knowledge of what social actions conventionally or ordinarily mean (Newman, 1982). It is in the former sense that understanding Ernie's strategies requires perspective-taking, and that the progression from seeing Ernie as sincere to seeing him as a trickster is a case of perspective-taking development.

Third, our model of social planning provides a potentially useful metaphor for constructing information-processing models of human planning. We suspect that much of human activity takes place, in some sense, in a mutual belief space. The objects to which we direct our plans and the facts that form the conditions for our actions are social objects. The implication of activity within mutual knowledge is that no conscious planning is taking place. Conscious planning usually comes into play only

when our ordinary course of action is blocked by some unusual condition. Our notation can help to specify several levels of human planning beyond mutual knowledge. First, we can define a level of consciously directed action. Using the notation, we would indicate an "Ernie believes" space directly enclosing a mutual belief space. That is, Ernie steps back from the situation to consider how to operate on it. He forms conscious, private thoughts about how to apply a particular plan or procedure under the current conditions. When Ernie consciously plans a speech act, for example, he considers how best to influence the current set of mutual beliefs that he shares with Bert. Acting on these mutual beliefs does not require considering Bert's perspective in particular, since the mutual belief space belongs as much to Ernie as to Bert.

When Ernie plans a strategic deception, another level is formed. As we saw in Figures 7 and 8, such deceptions require that we label the mutual belief space specifically as Bert's perspective. This is because Ernie had beliefs that contradicted the states that Bert thought were mutually believed. If Ernie were trying to repair a misunderstanding in a cooperative discourse with Bert, we would also have to assign the mutual belief space to Bert since Bert's misunderstanding (i.e., the thing he wrongly believes to be mutually believed) contradicts Ernie's actual beliefs. We can continue defining more complex planning spaces by adding additional embeddings, but there is, of course, a limit. Hansel's counter plan that we described elsewhere (Bruce & Newman, 1978) requires an embedding beyond those we needed to model Ernie's tricks. Interacting plans more complex than Hansel's are very rare.

Fourth, the model of social plans provides the beginnings of a conception of an important developmental transformation. While our

notation is very static and shows little or nothing of the process by which states at one level are transformed into states at another level, such transformations are crucial to human planning and its development. One important kind of transformation occurs when formerly private thoughts become mutually believed. At the very end of the skit, for example, Ernie rubs the trick in by asking Bert to share his half of a cookie. Some subjects believed that, by then, Bert realized what Ernie had done. Since Ernie also knew by then that Bert understood the trick, the trick itself became mutually believed. To represent that situation in the notation, we would have to include within the mutual belief space a set of spaces like Figure 7. In other words, it would be mutually believed that Ernie intended to trick Bert by getting him to think it is mutually believed that Ernie was trying to demonstrate his generosity.

The process of "collapsing" outside embeddings into the content of mutual belief is quite general and can be seen in the planning of speech acts. If Ernie is carefully planning how to (sincerely) express something to Bert, he is formulating the intention and action in his private thoughts. When he performs the speech act in Bert's presence, the intention gets entered into mutual knowledge. Again, but on a smaller scale, the contents of the private belief space collapse into the mutual beliefs.

Insofar as privately formulated plans regularly become part of mutual knowledge, "scripts" for these interacting plans can be formulated as shared cultural knowledge. We can imagine, for example, a trick script consisting of knowledge of how to step outside of mutual belief in order to deceive. Second-order deceptions can, of course, use this script. A poker player can get an opponent to think that he is bluffing when he

really is not. This is possible because the bluffing procedure itself is common knowledge among players. Thus, transformations from private to public again occur both microgenetically (as in planning a speech act) and ontogenetically (as in learning a trick script).

We began this paper with a discussion of three features that distinguished human plans from robot plans. We can see now that each of these features is also central to the process of development as we understand it. First, human development is a social as opposed to individual process, as is recognized by theorists as diverse as Piaget (1973) and Vygotsky (1978). We have briefly suggested the importance of others in providing the basis for conscious reflection outside of mutual belief. Human development in interaction with others is also interpretive rather than factual. Children do not learn a set of facts, they learn a framework for understanding their world. They learn how their actions are interpreted by others and what significance is attached to their repertoire of behavior. Studies of classroom interactions (Gearhart & Newman, 1980; Newman, et al., 1984), for example, show how the teacher "appropriates" the child's actions and fits them into her own interpretive system. It is the looseness of interaction with the opportunities for multiple understandings that appear to be the basis for learning in interaction. Finally, the process of appropriation is based on the use rather than the following of procedures. The notion of an "adaptive" as opposed to "routine" expert (Hatano, 1981) refers to just this aspect of human planning. Only an adaptive expert can teach a novice new skills. The ability to step outside of the accepted procedures and to see how they can be used is essential for creative problem solving. Likewise, the ability to step out even further and to reflect on how a novice is

understanding the situation and on how that understanding can be appropriated or used is important for successful teaching.

Ernie's trick gave us a specific case from which we have tried to make a general point. We have tried to argue that social planning is not just a specific domain of human planning, but is actually its basic form. Just as mutual knowledge was the basis for Ernie's trick, it is also the basis for our ordinary actions. Our plans of action are plans to act on the world that we share with others. Ernie demonstrates some of the properties of that world.

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Footnote

[1]Producing this belief is also the goal of another of Ernie's actions. As he is munching on the cookie, Ernie says: "See there? I told you I would share it with you." He is referring to his earlier assertion: "If that cookie belonged to me I would share it with you." It was Bert's not believing it that prompted Ernie's hypothetical demonstration. But for the demonstration to actually have proven the original point, Ernie would have had to own the cookie. (In his summary statement, Ernie conveniently leaves off the critical condition, "if the cookie belonged to me," though he clearly refers to the previous statement.) Ernie is acting as though he had promised to share and now has fulfilled that commitment. Such a statement would be false unless sharing had taken place. Thus, the virtual state of Ernie's sharing the cookie supports Ernie's statement in the mutual belief space while, in Ernie's real plan, Bert's resulting belief (that Ernie is stating that he kept the promise) produces in Bert the belief (that it is mutually believed) that Ernie shared the cookie.